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The Self-Diagnosability of a Computer

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Abstract—**Maximum capability for self-diagnosis with minimum additional hardware is the goal of every designer of a general purpose computer today. A yardstick with which the self-diagnosability of a system can be measured is proposed.**

A self-diagnosable computer can be described as a system consisting of two interconnected but independent machines: the main processor M_1 and a much smaller machine M_2 (about 5 to 10 percent of the size of M_1), which is capable of (programmatically) detecting and locating a fault in M_1. This fault location should be pinpointed within a small number of replaceable modules (integrated circuit chips, parallel-plate packages, or printed circuit cards) [1], [2].

The most commonly employed technique for diagnosis is to prepare a list of a complete set of tests $T=\{T_1, T_2, \cdots, T_n\}$ such that every failure in the system will cause one or more of these tests to fail [2]–[4]. Let the set $F=\{F_1, F_2, \cdots, F_m\}$ represent all possible single failure cases in the system. By taking the intersection of the sets of suspects for the failing test cases $T_{i1}, T_{i2}, \cdots, T_{ir}$ one arrives at a fault F_i. Let $k_1, k_2, \cdots, k_m$ be the number of suspected modules under the faults $F_1, F_2, \cdots, F_m$, respectively. In other words, during the Maintenance Routine [3] run, if tests T_{i1}, $T_{i2}, \cdots, T_{ir}$ fail, and the rest of the tests pass, then from a look-up table we arrive at the conclusion that fault F_i has occurred, and in order to correct this fault F_i we have to either replace k_i number of modules or examine each of these k_i modules by some other means and replace the bad one.

Clearly then, if N=total number of modules used in the machine,

$$\sum_{i=1}^{m} k_i \geq N. \tag{1}$$

Let p_i be the probability of occurrence of failure F_i, for $i=1, 2, \cdots, m$. Then assuming that at a given instance exactly one fault has occurred,

$$\sum_{i=1}^{m} p_i = 1. \tag{2}$$

Number $R_i=1/k_i$ is an indicator of the efficiency with which fault F_i can be repaired. The diagnostic efficiency of the entire system can be represented by

$$R = \frac{1}{\sum_{i=1}^{m} k_i p_i}. \tag{3}$$

This number R can be called the "resolution" of the entire system. The comparative figure of merit of a diagnostic subsystem is then

$$\frac{R}{\text{cost}} \tag{4}$$

where the cost includes the cost of hardware in M_2, of software, of development, and of running time of the maintenance routine.

If the maintenance routine only detects, and does not locate a fault, then R assumes its minimum possible value

$$R_{\min} = \frac{1}{N}. \tag{5}$$

This implies that one has to examine all N modules of the machine to locate the faulty module.

The resolution R is maximum when every failure can be traced down exactly to one module, i.e. $k_i=1$, for $1 \leq i \leq n$. Then from (3), resolution becomes

$$R_{\max} = \frac{1}{\sum_{i=1}^{m} p_i} = 1. \tag{6}$$

If all modules are assumed to have equal probability of failure, then the probability of occurrence of failure F_i is given by

$$p_i = \frac{k_i}{\sum_{i=1}^{m} k_i} \tag{7}$$

and the resolution of the machine by substituting (7) in (3) turns out to be

$$R_e = \frac{\sum_{i=1}^{m} k_i}{\sum_{i=1}^{m} k_i^2}. \tag{8}$$

In absence of any statistical data available on the probability of various failures, (8) would be a good index of the diagnosability of a system.

In the author's opinion the resolution in (8) is a very important figure in the specification of any machine with diagnostic capability. The manufacturer should specify it, and the customer should ask for it. As discussed above, in general, R_e will have a value between 1 and $1/N$.

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